Final Technical Report
USGS Cooperative Agreement G16AC00357
Incorporating Real-time GNSS into ShakeAlert

Pacific Northwest Geodetic Array
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Abstract

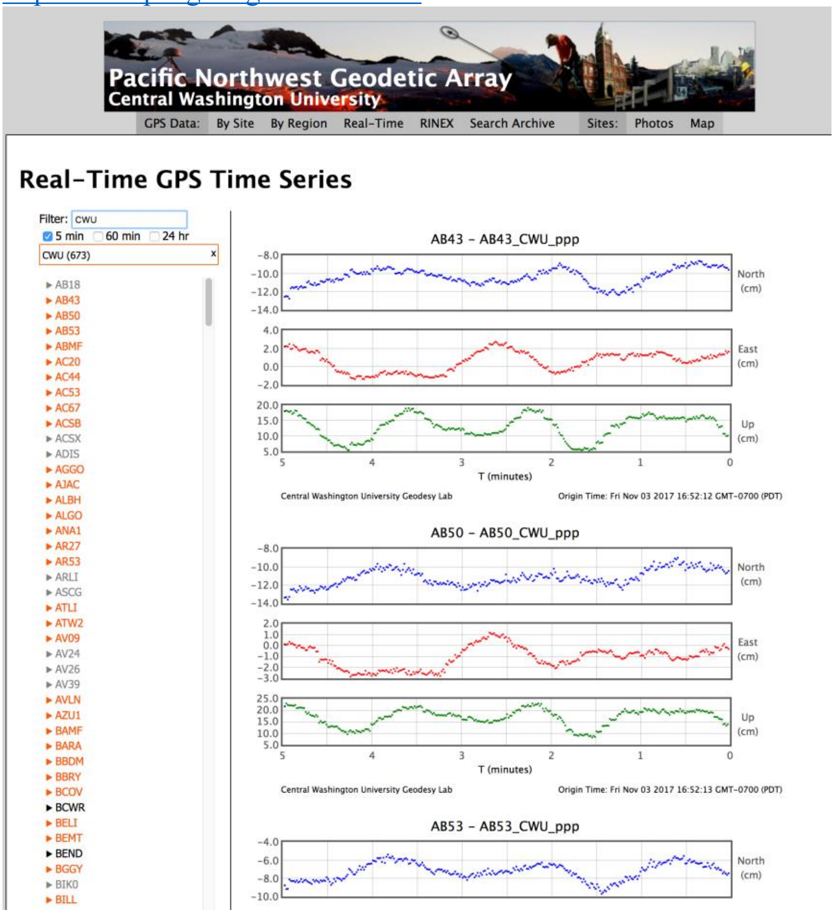
This cooperative agreement comprised four tasks, as described in the revised work plan. As of the end of the agreement period August 31 2017:

1. We expanded CWU's ambiguity-resolved, real-time Precise Point Positioning using the Fastlane positioning system to ~300 western US stations to create a ShakeAlert GNSS Analysis Center.
2. We are formally merging CWU solutions within a Kalman filter using CWU merging filters and messaging services developed under NASA's READI initiative. We have not yet implemented merging of position streams from other USGS ShakeAlert GPS analysis centers for the purposes of ShakeAlert, but this is simply a matter of configuration pending specification of which independent analyses to combine.
3. We are now streaming CWU Fastlane solutions to the three ShakeAlert centers at Menlo Park, UC Berkeley, Caltech & U. of Washington.
4. We have further developed the dedicated telemetry system using a combination of wireless and VSAT telemetry.

Each of these four tasks is described more fully below.

1. Fastlane Real-Time Precise Point Positioning

FastLane PPP is fully functioning side-by-side with our older system based on GIPSY which we use to vet its accuracy. We are currently beta-testing a single instance of it, handling ~300 stations (it is fully multi-threaded) on one 26-core Dell server running Linux Centos 6. The performance is very good with reasonable load averages, and the memory footprint remains small over time (ie, no discernible memory leaks), and depends solely on how many threads of PPP are specified. We log internal metrics from only a few stations, just to be able to handle the flow of information generated by the logging system. Currently the overall system is stable but more work needs to be done to make the PPP better handle sites with unusually high noise, for which we see difficulty either in acquiring or re-acquiring a solution. This does not impact processing performance, nor resultant solution quality, of good stations providing clean data processed simultaneously, but it is pointing us towards aspects of different algorithms that we need to improve. The front-end to Fastlane has also been slightly redesigned in order to read messages from our BNC replacement rather than BNC, but the bias estimation and positioning routines remain unchanged as methods in the Fastlane PPP class. Also, the class includes methods to transmit raw messages back, along with the PPP solution for the given epoch, as well as any other parameter estimated within the PPP process (eg, WETZ). Real-time PPP time series may be viewed at http://www.panga.org/realtime/data



RT-PPP instantaneous positions relative to true-of-date apriori (based on long-term trajectory models) may be monitored via the GPS Cockpit application (Note: ~300 stations were available at the end of this cooperative agreements, not 560 as shown for November 2017):

2. Solution Merging

We are not yet merging independent solutions for ShakeAlert, and are awaiting specification by USGS about whose solutions should be merged and which stations. We are further developing our merging system for the NOAA Tsunami Warning Centers, with this work funded primarily by NASA-ESI. Our 3-institution merging Kalman Filter is up and running at CWU, merging CWU, JPL and SIO solutions into a single stream for the purposes of streaming combined solutions to the Pacific and National Tsunami Warning Centers in Honolulu, HI and Palmer, AK. It has also been installed and is running at UCSD-SIO and JPL. As of July 2017 the two TWCs are receiving CWU's instance of the 3-way merged stream, and SIO and JPL are in the process of getting the two TWCs to receive their respective merged streams as well. We are working with JPL and SIO on a weekly basis to work out issues as they arise.

The merging script continues to undergo development. Discrete, numbered versions are released when sets of changes are complete. These releases have included both fixes for bugs identified by CWU, JPL or SIO, and also changes suggested by discussion in the weekly teleconferences.

A more thorough refactoring of the script has also been undertaken, but is not yet complete. This refactor was begun in part to address memory use issues seen by SIO, but also will result in more organized code for future development, better test coverage, and improved code performance.

3. Streaming rtPPP solutions to ShakeAlert centers at U. Washington, UC Berkeley and Caltech

rtPPP solutions streaming has been established to UW, UC Berkeley and Caltech in geoJSON format via RabbitMQ message brokering software, suitable to be ingested by the geosjon2ew Earthworm plugin.

The work done on the geojson2ew plugin by UC Berkeley has allowed us to shift away from RabbiMQ "queues", which are limited to a single client connection, to "exchanges", which can provide data to a number of clients. This change resulted in a simpler configuration of our RabbitMQ server, more streamlined publishing of data from our processing system, and greater ease of monitoring the stream availability.

Metadata for the sites that are streamed is available as a text file on the CWU PANGA website. The format of the file is as defined by the USGS. Some details of that format have remained under discussion. We are updating the metadata file to match the recommended format as it is firmed up.

The solutions provided are from our older processing system based on GIPSY. Typically there are 30-40 sites streaming. When the Fastlane processing comes out of beta, we will switch to providing those solutions.

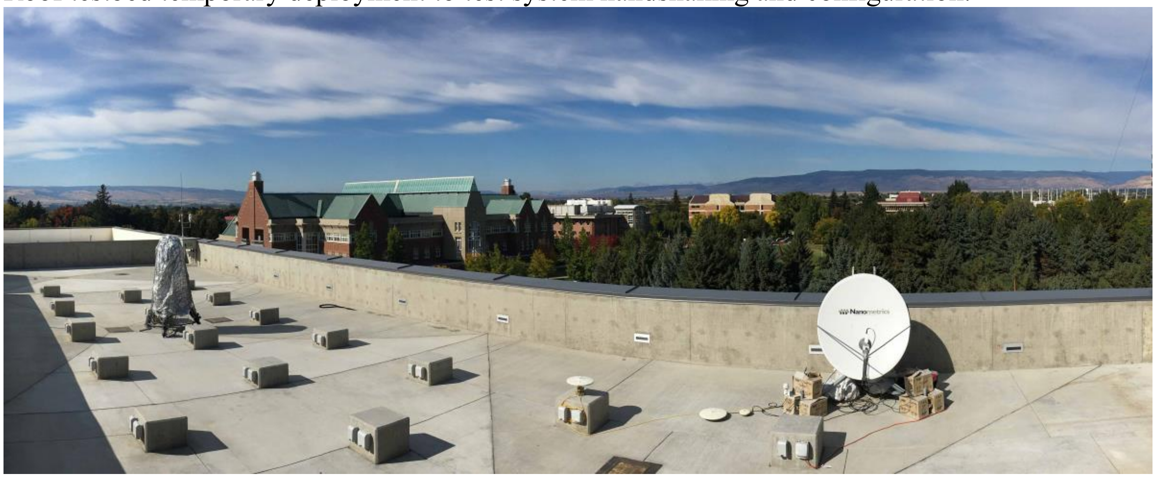
4. Developed the Nanometrics/Libra VSAT Telemetry system

Data stream throughput and latency tests were completed (by CWU and Nanometrics in Quebec), baud rates and TDMA transmission frames to meet system requirements for EEW have been set, satellite lease and power/frequency ranges were selected; hardware was ordered from Nanometrics and satellite communications components (RF transceiver, splitter/combiner, and router) for one satellite hub (at CWU) and 10 remote transceiver hardware for Libra delivered to CWU. CWU hub mounting hardware was designed and and engineered by Integrus Architects of Spokane, WA. The 2.4 meter mounting pedestal constructed by Lydig Construction Corp.\ and welded into structural I-beams beneath the roof of the Geological Sciences building. Conduit was installed to the PANGA data closet and all equipment installed. Satellite hub transceiver and power backup were installed in communications closet by CWU's Telecom Dept.Land use permits have been accepted by 8 coastal sites and Puget Sound VSAT locations. Operations and setup training was completed in July 2017. System status as of November 1 2017, after end of agreement, is that 8 remote stations have been deployed and are operating essentially without hitches. The network plan is shown below:

Map of planned geodetic stations with VSAT telemetry systems

Construction of the downlink node atop CWU Geological Sciences building:

Roof testbed temporary deployment to test system handshaking and configuration:



(Temporary) Site: ROOF-Testbed
Location: Ellensburg, WA
GPS Receiver(s): SEPT POLARXS; TRIMBLE NETR9/NETRS
GPS Antenna(s): TRM57971.00; TRM41249.00; TRM33429.00-GP
Role: Bench testing multiple GPS receiver manufacturers, antennas, and varying data stream formats before deployment to the field. This station will be redeployed to its final location once the rest are installed.